ON THE

ULTIMATE SECRETING STRUCTURE,

AND ON THE

LAWS OF ITS FUNCTION.

BY

JOHN GOODSIR, M.W.S.,

CONSERVATOR OF THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS, EDINBURGH.

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XVIII.—*On the Ultimate Secreting Structure, and on the Laws of its Function.* By JOHN GOODSIR, M.W.S., Conservator of the Museum of the Royal College of Surgeons, Edinburgh.

(Read 21st March 1842.)

MALPIGHI was the first to announce that all secreting glands are essentially composed of tubes, with blind extremities. MÜLLER, by his laborious researches, has brought this department of the anatomy of glands to its present comparatively perfect condition. PURKINJE announced his hypothesis of the secreting function of the nucleated epithelium of the gland ducts, but made no statement to shew that he had verified it by observation. SCHWANN suggested that the epithelium of the mucous membranes might be the secreting organ of these surfaces. HENLE described minutely the epithelium cells which line the ducts of the principal glands and follicles, but did not prove that these are the secreting organs. The same anatomist has stated, that the terminal extremities of certain gland ducts are closed vesicles, within which the secretion is formed, and which contain nucleated cells. HENLE has not, therefore, verified the hypothesis of PURKINJE, although he is correct in stating that the terminal vesicles of certain gland ducts are closed. It will be shewn, in the course of this paper, that the secretion is not formed, as HENLE has asserted, in the closed vesicles, but in the nucleated cells themselves.

The discrepant observations of BOEHM and KRAUSE on the glands of PEYER, were in some measure reconciled by HENLE, who referred them to the same class of structures, as the closed vesicular extremities of the ducts of compound glands. Dr ALLEN THOMSON has made the important observation, that the primitive condition of the gastric and intestinal gland is a closed vesicle. WASMANN described the structure of the gastric glands in the pig; and his description will be fully explained by the observations and views contained in the present paper. HALLMAN has given a detailed account of the testicle of the ray, which closely resembles that of the *Squalus cornubicus*, as described in another part of this communication. He found the vesicles closed, but did not detect the mode of development of the spermatozoa, or the continual growth of the gland itself. None of the recent observations on the development of the spermatozoa have proved, that the vesicles, in which they are formed, are the epithelium cells of the ducts of the testicle. I am indebted to Dr ALLEN THOMSON for directing my attention to a notice in VALENTINE's Repertorium, 1841, of a Dissertation by ERDL, de Heli-

cis Algiræ vasis sanguiferis, 1840, in which he describes, in the kidney of that mollusk, cells, the nuclei of which pass out by the duct of the gland. It does not appear, however, that ERDL had discovered the uric acid within the cell.

I have now stated all that is known at present of this subject. No one, as far as I am aware, has proved that secretion takes place within the nucleated cell, or has pointed out the intimate nature of the changes which go on in a secreting organ, during the performance of its function. It is the object of the present communication to supply this deficiency in physiological science.

If the membrane, which lines the secreting portion of the internal surface of the ink-bag of *Loligo sagittata* (LAMARK) be carefully freed from adhering secretion by washing, it will be found to consist almost entirely of nucleated cells, of a dark brown or black colour. These cells are spherical or ovoidal, and measure from 1.000th to 2.000th of an inch in their longer diameters. Their nuclei consist of cells, grouped together in a mass. Between these composite nuclei, and the walls of their containing cells, is a fluid of a dark brown colour. This fluid resembles, in every respect, the secretion of the ink-bag itself. It renders each cell prominent and turgid, and is the cause of its dark colour.

The dilated terminal extremities of the ducts in the liver of *Helix aspersa* (MÜLLER) contain a mass of cells. If one of these cells be isolated, and examined, it presents a nucleus, consisting of one or more cells. Between the nucleus and the wall of the containing cell, is a fluid of an amber tint, and floating in this fluid are a few oil globules. This fluid differs in no respect from the bile, as found in the ducts of the gland. The cells measure from 1.000th to 2.000th of an inch.

If a portion of the ramified glandular organ, which opens into the fundus of the stomach of *Uraster rubens* (AGASSIZ) be examined, its internal surface is found to be lined with cells; between the nucleus of each of which, and the wall of the cell itself, a dark brown fluid is situated. The organ secretes a fluid, supposed to be of the nature of bile. The cells measure from 4.000th to 5.000th of an inch.

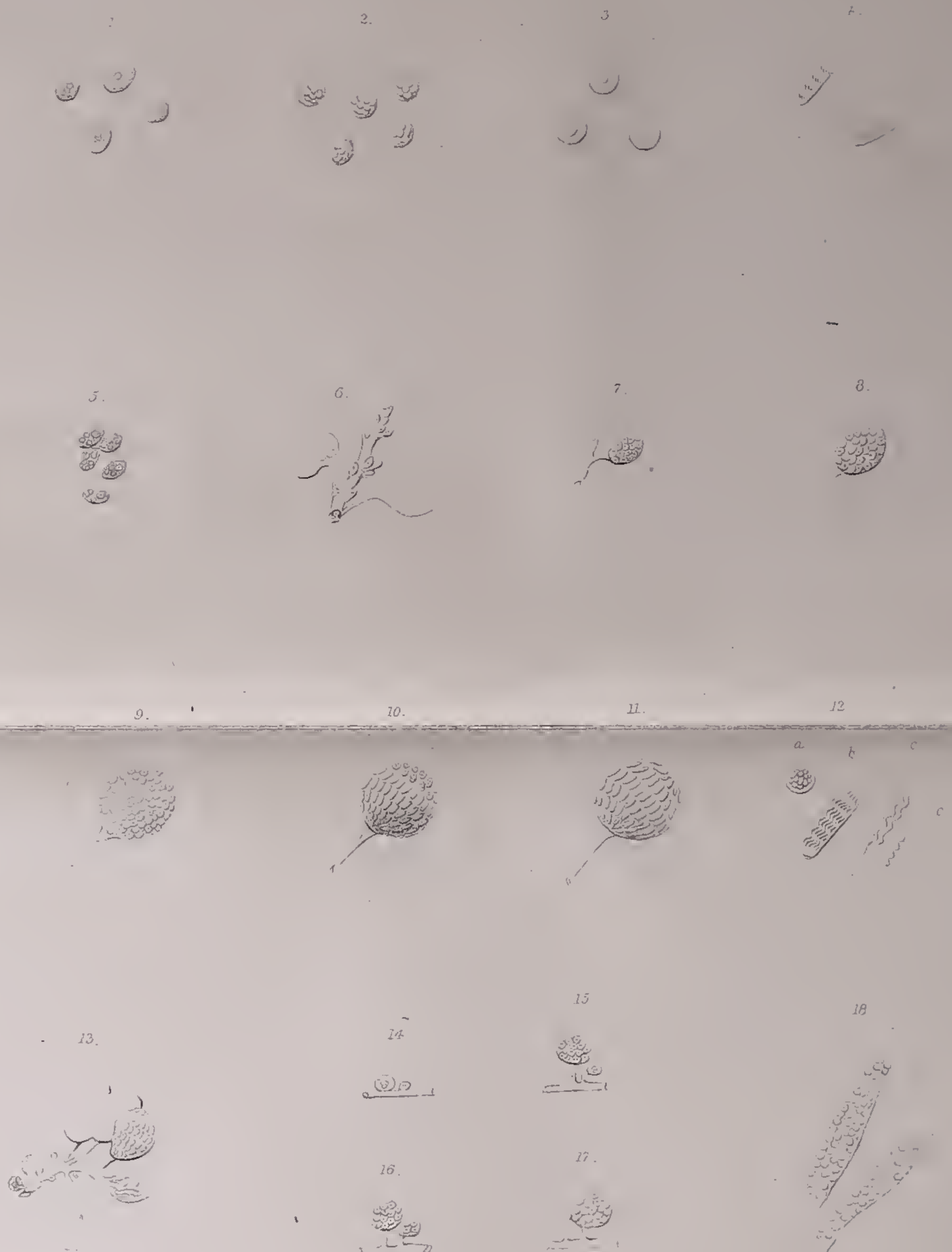
The dark brown ramified cæca of the same animal exhibit on their internal surfaces an arrangement of nucleated cells, the cavities of which contain a brown fluid. These cæca are also supposed to perform, or to assist in the performance of the function of the liver.

The liver of *Modiola vulgaris* (FLEMING) contains masses of spherical cells, measuring about 3.000th inch in diameter. Between the nucleus and the wall of each of these cells, a light brown fluid is situated, bearing a close resemblance to the bile in the gastro-hepatic pouches.

The nucleated cells, which are arranged around the gastro-hepatic pouches of the *Pecten opercularis*, are about 2.000th of an inch in diameter, irregular in shape, and distended, with a fluid resembling the bile.

The hepatic organ, which is situated in the loop of intestine of *Pirena Pru-*

PLATE VIII. Trans. Royal Soc Vol XV



num (Fleming), consists of a mass of nucleated cells. These cells are collected in groups, in the interior of larger cells or vesicles. The nucleated cells measure about 3.000th of an inch, and are filled with a light brown bilious fluid.

The hepatic organ, situated in the midst of the reproductive apparatus, and in the loop of the intestine of *Phallusia vulgaris* (Forbes and Goodsir), consists of a number of vesicles, and each vesicle contains a mass of nucleated cells. These cells measure about 2.000th of an inch, and contain a dark brown bilious fluid.

The hepatic organ, in the neighbourhood of the stomach, in each of the individuals of the compound mollusk, the *Alpidium-Ficus* (Linnæus), consists of nucleated cells, which measure 4.000th of an inch in diameter, and contain in their cavities a reddish brown fluid.

The liver of *Loligo sagittata* (Lamark), contains a number of nucleated cells, ovoidal and kidney-shaped, ranging in diameter from 1.000th to 3.000th of an inch. These cells are distended with a brown bilious fluid.

The nucleated cells in the liver of *Aplysia punctata* (Cuvier), measure from 1.000th to 3.000th of an inch, and are full of a dark brown fluid.

The ultimate vesicular cæca of the liver of *Buccinum undatum*, contain ovoidal vesicles of various sizes. These vesicles contain more or less numerous nucleated cells. The cells are full of a dark brown fluid.

The hepatic cæca in the liver of *Patella vulgata*, contain vesicles about 1.000th of an inch in diameter. Each of these vesicles encloses a body which consists of a number of nucleated cells, full of a dark fluid resembling the bile.

The simple biliary apparatus, which surrounds the gastric portion of the intestinal tube of *Nereis*, contains nucleated cells, about 3.000th of an inch in diameter, full of a light brown fluid.

The hepatic cæca of *Carcinus Mœnas* contains cells full of a fluid of an ochrey colour, along with numerous oil globules. The cells measure about 2.000th of an inch.

The hepatic cæca of *Carabus catenulatus* (Fabricius) contain, attached to their internal surfaces, cells measuring about 1.000th of an inch in diameter. Between the nuclei, and the cell walls, a brown liquid containing numerous granules is situated.

The kidney of *Helix aspersa* (Müller) is principally composed of numerous transparent vesicles. In the centre of each vesicle is situated a cell full of a dead white granular mass. This gland secretes pure uric acid.

The ultimate elements of the human liver are nucleated cells, measuring about 1.000th of an inch. Between the nucleus and the cell-wall is a light brown fluid, with one or two oil globules floating in it.

The vesicular cæca, in the testicle of *Squalus cornubicus*, contain nucleated cells which ultimately exhibit in their interior bundles of spermatozoa.

The generative cæca of *Echiurus vulgaris* (Lamark) contain cells full of minute spermatozoa.

Aplysia punctata secretes from the edge and internal surface of its mantle a quantity of purple fluid. The secreting surface of the mantle consists of an arrangement of spherical nucleated cells, about 3.000th of an inch in diameter. These cells are distended with a dark purple matter.

The edge and internal surface of the mantle of *Janthina Fragilis* (Lamark), the animal which supplied the Tyrian dye, secretes a deep bluish purple fluid. The secreting surface consists of a layer of nucleated cells, about 2.000th of an inch in diameter, distended, with a dark purple matter.

If an ultimate acinus of the mammary gland of the bitch be examined during lactation, it is seen to contain a mass of nucleated cells. These cells are generally ovoidal, rather transparent, and measure about 2.000th of an inch in the long diameter. Between the nucleus and the cell wall of each, a quantity of fluid is contained, and in this fluid float one, two, three, or more oil-like globules, exactly resembling those of the milk.

In addition to the series of examples already given, I might adduce many others to prove that secretion is a function of the nucleated cell. Some secretions, indeed, are so transparent and colourless, as to render ocular proof of their original formation within cells impossible ; and we do not yet possess chemical tests of sufficient delicacy for the detection of such minute quantities. The examples I have selected, however, shew that the most important and most striking secretions are formed in this manner. The proof of the universality of the fact, in reference to the glandular structures which produce colourless secretions, can only rest at present on the identity of the anatomical changes which occur in their cellular elements. This part of the proof I shall enter upon in another part of the paper.

The secretion within a primitive cell is always situated between the nucleus and the cell-wall. Now, as we know that the nucleus is the reproductive organ of the cell, that it is from it, as from a germinal spot, that new cells are formed, I am inclined to believe that it has nothing to do with the formation of the secretion. I believe that the cell-wall itself is the structure, by the organic action of which each cell becomes distended with its peculiar secretion, at the expense of the ordinary nutritive medium which surrounds it.

The ultimate secreting structure, then, is the primitive cell, endowed with a peculiar organic agency, according to the secretion it is destined to produce. I shall henceforward denominate it the primary secreting cell. It consists, like other primitive cells, of three parts,—the nucleus, the cell-wall, and the cavity. The nucleus is its generative organ, and may or may not, according to circumstances, become developed into young cells. The wall is the organ by the agency of which the cell performs the duty assigned to it. The cavity is the receptacle in which

the secretion is retained till the quantity has reached its proper limit, and till the period has arrived for its discharge.

Each primary secreting cell is endowed with its own peculiar property, according to the organ in which it is situated. In the liver it secretes bile—in the mamma, milk, &c.

The primary secreting cells of some glands have merely to separate from the nutritive medium a greater or less number of matters already existing in it. Other primary secreting cells are endowed with the more exalted property of elaborating from the nutritive medium matters which do not exist in it.

The discovery of the secreting agency of the primitive cell does not remove the principal mystery in which this function has always been involved. One cell secretes bile, another milk; yet the one cell does not differ more in structure from the other than the lining membrane of the duct of one gland from the lining membrane of the duct of another. The general fact, however, that the primitive cell is the ultimate secreting structure, is of great value in physiological science, inasmuch as it connects secretion with growth, as phenomena regulated by the same laws. The force, of whatever kind it may be, which enables one primary formative cell to produce nerve and another muscle, by an elaboration within itself of the common materials of nutrition, is identical with that force which enables one primary secreting cell to elaborate bile and another milk.

Instead of growth being a species of imbibing force, and secretion on the contrary a repulsive, the one centripetal, the other centrifugal, they are both centripetal. Even in their later stages the two processes, growth and secretion, do not differ. The primary formative cell, after becoming distended with its peculiar elaborated nutritive matter, in some instances changes its forms and arrangements according to certain laws, and then, after a longer or shorter period, dissolves and disappears in the inter-cellular space in which it is situated, its materials being taken up by the circulating system, if it be an internal, and being merely thrown off if it be an external cell. The primary secreting cell, again, after distention with its secretion, does not change its form so much as certain of the formative cells, but the subsequent stages are identical with those of the latter. It bursts or dissolves, and throws out its contents either into ducts or gland cavities (both of which, as I shall afterwards shew, are inter-cellular spaces), or from the free surface of the body.

The general fact of every secretion being formed within cells, explains a difficulty which has hitherto puzzled physiologists, viz., why a secretion should only be poured out on the free surface of a gland-duct or secreting membrane.

"Why," says Professor Müller, "does not the mucus collect as readily between the coats of the intestine as exude from the inner surface? Why does not the bile permeate the walls of the biliary ducts, and escape on the surface of the liver, as readily as it forces its way outwards in the course of the ducts? Why

does the semen collect on the inner surface only of the tubuli semeniferi, and not on their exterior, in their interstices? The elimination of the secreted fluid on one side only of the secreting membrane, viz. on the interior of the canals, is one of the greatest enigmas in physiology." MÜLLER proceeds to explain this enigma by certain hypotheses; but the difficulty disappears, the mystery is removed, when we know that the secretion only exists in the interior of the ripe cells of the free surface of the ducts or membrane, and is poured out or eliminated simply by the bursting and solution of these superficial cells.

In the former part of this paper I have confined my observations to the structure and function of the ultimate secreting element, the primary secreting cell. I now proceed to state the laws which I have observed to regulate the original formation, the development, and the disappearance of the primary organ. This subject necessarily involves the description of the various minute arrangements of glands and other secreting structures. As the development of a subject so rich as this already has been, and still promises to be, would much exceed the limits of a single communication, I restrict myself at present to the announcement of the laws themselves, and to a statement of a few facts in illustration. I reserve for future communications, which I hope to have the honour of submitting to this Society, a detailed description of the minute changes which are constantly taking place in glands during the performance of their function.

If the testicle of *Squalus cornubicus* (GMELIN) be examined when the animal is in a state of sexual vigour, the following arrangements of structure present themselves.

The gland consists of a number of lobes separated, and at the same time connected by a web of filamentous tissue, in which ramify the principal bloodvessels.

The lobes, when freed from this tunic, present on their surface a number of vesicles. When the gland is dissected under water, and one of the lobes is raised out of its capsule, an extremely delicate duct is observed to pass from it into the substance of the capsule, to join the ducts of the other lobes.

When a section is made through one of the lobes, it becomes evident that the vesicles are situated principally on its exterior.

If a small portion be macerated in water for a few hours, and dissected with a couple of needles, there are observed attached to the delicate ducts which ramify through the lobe vesicles in all stages of development. These stages are the following:—1*st*, A single nucleated cell attached to the side of the duct, and protruding, as it were, its outer membrane.

2*d*, A cell containing a few young cells grouped in a mass within it; the parent cell presenting itself more prominently on the side of the duct.

3*d*, A cell attached by a pedicle to the duct, the pedicle being tubular, and communicating with the duct; the cell itself being pyriform, but closed and full of nucleated cells.

4th, Cells larger than the last, assuming more of a globular form, still closed, full of nucleated cells, and situated more towards the surface of the lobe.

5th, The full-sized vesicles already described as situated at the surface of the lobe. These vesicles are spherical, perfectly closed; that part of the wall of each which is attached to the hollow pedicle forms a diaphragm across the passage, so that the vesicle has no communication with the ducts of the gland. The contents of the vesicles are in various stages of development. Those least advanced are full of simple nucleated cells; in others, the included cells contain young cells in their interior, so that they appear granular under low powers; in others, the included cells have begun at a certain part of the vesicle to elongate into cylinders, with slightly rounded extremities. In others the cylindrical elongation has taken place in all the included cells, with the exception of a few, which still retain the rounded form, at a spot opposite to that part of the vesicle in which the change commenced, and at the same time it may be observed, that the cylindrical cells have become arranged in a spiral direction within the parent vesicle. *Lastly*, Vesicles exist in which all the cells are cylindrical, and are arranged within its cavity in a spiral direction.

The changes which occur in the included nucleated cells of the vesicle are highly interesting. After the nucleus of each has become developed into a mass of cells, the parent cell becomes, as has been stated, cylindrical. The change in the shape of the cell is contemporaneous with the appearance of a spiral arrangement of the included mass of cells. This spiral arrangement is also contemporaneous with an elongation of each cell in the mass, in the direction of the axis of the parent cell. When the elongation has reached its maximum, the original mass of included cells has assumed the appearance of a bunch of spirals, like cork-screws arranged one with another, spiral to spiral. In particular lights the cylindrical cell presents alternate spots of light and shade, but by management of the illumination, the included spiral filaments become evident; the light and shade is seen to arise from the alternate convexities and concavities of the spiral filaments, combined in a spiral bundle.

In vesicles more advanced, the walls of the cylindrical cells have become attenuated.

In other vesicles the diaphragms across their necks have dissolved or burst, the bundles of spiral filaments float along the ducts of the gland, or separate into individual spiral filaments. These filaments are completely developed spermatozoa, pointed and filamented at both extremities, thicker and spiral in the middle.

In the centre of the lobe where the smaller ducts meet to form the principal duct, there is a mass of grey gelatinous matter through which the ducts pass. This gelatinous matter consists of a number of cells lying between the converging ducts, and from their peculiar appearance not presenting the usual nuclei. I am inclined to believe that they are either vesicles which have never become developed

on account of the pressure of the surrounding parts, or that they are old vesicles in a state of atrophy after the expulsion of their contents.

Having now described the changes which are constantly taking place in the testicle of this shark when the organ is in a state of functional activity, I must defer till a future occasion an account of similar changes which occur in the parenchyma of an order of glands, of which the one already described may be considered as a type. I may state, however, that I have ascertained the following general facts in reference to glands of this order :—

1*st*, The glandular parenchyma is in a constant state of change, passing through stages of development, maturity, and atrophy.

2*d*, This state of change is contemporaneous with, and proportional to, the formation of the secretion, being rapid when the latter is profuse, and *vice versa*.

3*d*, There are not, as has hitherto been supposed, two vital processes going on at the same time in the gland, growth and secretion, but only one, viz. growth. The only difference between this kind of growth and that which occurs in other organs being, that a portion of the product is from the anatomical condition of the part thrown out of the system.

4*th*, The vital formative process which goes on in a gland, is regulated by the anatomical laws of other primitive cellular parts.

5*th*, An acinus is at first a single nucleated cell. From the nucleus of this cell others are produced. From these, again, others arise in the same manner. The parent cell, however, does not dissolve away, but remains as a covering to the whole mass, and is appended to the extremity of the duct. Its cavity, therefore, as a consequence of its mode of development, has no communication with the duct.

The original parent cell now begins to dissolve away, or to burst into the duct at a period when its contents have attained their full maturity. This period varies in different glands, according to a law or laws impressed upon each of them.

6*th*, In the gland there are a number of points from which acini are developed, as from so many centres. These I denominate the germinal spots of the gland.

7*th*, The secretion of a gland is not the product of the parent cell of the acinus, but of its included mass of cells. The parent cell or vesicle may be denominated the primary cell; its included nucleated cells, after they have become primary secreting cells, may be denominated secondary cells of the acinus.

8*th*, The matter which passes off by a duct of a gland may be, 1*st*, A true secretion, that is, matter formed in the primary secreting cell cavities; or, 2*d*, A mixture of a fluid formed in these cell cavities with the developed or undeveloped nuclei of the cells themselves; and, 3*d*, It may be a number of secondary cells passing out entire.

If a portion of the liver of *Carcinus Mænas* is carefully examined, it is observed that each of the follicles of which it consists presents the following struc-

ture :—The blind extremity of the follicle is slightly pointed, and contains in its interior a mass of perfectly transparent nucleated cells. From the blind extremity downwards, these cells appear in progressive states of development. At first they are mere primitive nucleated cells; further on they contain young cells; and beyond this they assume the characters of primary secreting cells, being distended with yellow bile, in which float oil globules, the oil in some instances occupying the whole cell. Near the attached extremity of the follicle an irregular passage exists in the midst of the cells, and allows the contents of the cells which bound it to pass on to the branches of the hepatic duct.

This arrangement of the secreting apparatus may be taken as the type of an order of glands, which consist of follicles more or less elongated. Growth in glands of this kind is regulated by the following laws :—

1st, Each follicle is virtually permanent, but actually in a constant state of development and growth.

2d, This growth is contemporaneous with the function of the gland, that function being merely a part of the growth, and a consequence of the circumstances under which it occurs.

3d, Each follicle possesses a germinal spot situated at its blind extremity.

4th, The vital action of some follicles is continuous, the germinal spot in each never ceasing to develope nucleated cells, which take on the action of, and become primary secreting cells, as they advance along the follicle. The action of other follicles is periodical.

5th, I have not been able to satisfy myself, but I am inclined to believe, that the wall of the follicle is also in a state of progressive growth, acquiring additions to its length at its blind extremity, and becoming absorbed at its attached extremity.* A progressive growth of this kind would account for the steady advance of its attached contents, and would also place the wall of the follicle in the same category with the primary vesicle or wall of the acinus in the vesicular glands.

6th, The primary secreting cells of the follicle are not always isolated. They are sometimes arranged in groups, and when they are so, each group is enclosed within its parent cell, the group of cells advancing in developement according to its position in the follicle, but never exceeding a particular size in each follicle.

I am inclined to believe, although of this I have not satisfied myself, that there is an order of glands, namely, those with very much elongated and anastomosing ducts, which do not possess germinal spots in particular situations, but in which these spots are diffused more uniformly over the whole internal surface of the ducts. I am the more inclined to believe this, from what I have observed in

* Mr Henry Goodsir, in a paper on the Development and Metamorphoses of *Caligus*, read in the Wernerian Society, April 1842, has stated that the wall of the elongated and convoluted follicle, which constitutes the ovary in that genus, grows from its blind to its free extremity, at the same rate as the eggs advance in development and position.

certain secreting membranes. Thus the membranes which secrete the purple of *Aplysia* and *Janthina* are not covered with a continuous layer of purple secreting cells, but over the whole surface, and at regular distances, there are spots, consisting of transparent, colourless nucleated cells, around which the neighbouring cells become coloured. Are these transparent cells the germinal spots of these secreting membranes? And may not the walls of the elongated tubes, and the surfaces of the laminæ within certain glands, have a similar arrangement of germinal spots?

We require renewed observations on the original development of glands in the embryo. From the information we possess, however, it appears that the process is identical in its nature with the growth of a gland during its state of functional activity.

The so-called blastema, which announces the approaching formation of a gland in the embryo, in some instances precedes, and is in other instances contemporaneous with, the conical blind protrusion of the membrane upon the surface of which the future gland is to pour its secretion.

In certain instances it has been observed that the smaller branches of the duct are not formed by continued protrusion of the original blind sac, but are hollowed out independently in the substance of the blastema, and subsequently communicate with the ducts.

It appears to be highly probable, therefore, that a gland is originally a mass of nucleated cells, the progeny of one or more parent cells, mediate or immediate products of the yelk; that the membrane in connexion with the embryo gland may or may not, according to the case, send a portion of the membrane, in the form of a hollow cone, into the mass; but whether this happens or not, the extremities of the ducts are formed as closed vesicles, and then nucleated cells are formed within them, and are the parents of the epithelium cells of the perfect organ.

Dr Allen Thomson has ascertained that the follicles of the stomach and large intestine are originally closed vesicles. This would appear to shew that a nucleated cell is the original form of a follicle, and the source of the germinal spot which plays so important a part in its future actions.

The ducts of glands are therefore inter-cellular passages. This is an important consideration, inasmuch as it ranges them in the same category with the intercellular passages and secreting receptacles of vegetables.

I conclude, therefore, from the observations which I have made—1*st*, That all the true secretions are formed or selected by a vital action of the nucleated cell, and that they are first contained in the cavity of that cell; 2*d*, That growth and secretion are identical—the same vital process, under different circumstances.

EXPLANATION OF THE PLATE (VIII).

Fig. 1. Four secreting cells from the ink bag of *Loligo sagittata.*

Fig. 2. Five cells from the liver of *Patella vulgata.* In this instance the bile is contained in the cavities of the secondary cells, which constitute the nucleus of the primary cell.

Fig. 3. Three cells from the kidney of *Helix aspersa.* The contained secretion is dead white, and presents a chalky appearance.

Fig 4. Two cells from the vesicles of the testicle of *Squalus cornubicus.* The contained bundles of spermatozoa are developed from the nucleus,—each spermatozoon being a spiral cell.

Fig. 5. Five cells from the mamma of the bitch. In addition to their nuclei, these cells contain milk globules.

Fig. 6. A portion of duct from the testicle of *Squalus cornubicus.* A few nucleated cells, the primary or germinal cells of the future acini are attached to its walls.

Fig. 7. The primary cell of an acinus in a more advanced stage. The nucleus has produced a mass of of young cells. The pedicle appears to have been formed by the germinal cell carrying forward the wall of the duct. A diaphragm accordingly presents itself, across the neck of the pedicle.

Fig. 8. A primary cell in a more advanced stage.

Fig. 9. A primary cell still more advanced.

Fig. 10. Some of the secondary cells, products of the nucleus of the primary cell, are cylindrical, and are arranged in a spiral.

Fig. 11. The change into cylinders, and the spiral arrangement completed.

Fig. 12. *a,* One of the secondary cells; its nucleus a mass of young cells. *b,* A secondary cell elongated into a cylinder, each cell of its composite nucleus elongated into a spiral. *c,* The spiral cells, or spermatozoa, free.

Fig. 13. A bunch of acini, in various states of development, maturity, and atrophy.

The four following Figures are diagrams, arranged so as to illustrate the intimate nature of the changes which occur in vesicular glands when in a state of functional activity.

Fig. 14. A portion of gland duct with two acini. One of the acini is a simple primary cell: the other is in a state of development, its nucleus producing young cells.

Fig. 15. Both acini are advancing: the second has almost reached maturity.

Fig. 16. The second acinus is ready to pour out its contents, the first to take its place.

Fig. 17. The second acinus is in a state of atrophy, the first is ripe.

Fig. 18. Two follicles from the liver of *Carcinus mœnas.* The colourless germinal spot is at the blind extremity of the follicle. The secreting cells become distended with bile and oil, as they recede from the germinal spot.